ON

COLOUR-SIGHT AND COLOUR-BLINDNESS.

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IN ITS RELATION TO

RAILWAY AND SEA SIGNALS,

READ BEFORE THE

GLASGOW PHILOSOPHICAL SOCIETY,

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BY

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ON

COLOUR-SIGHT AND COLOUR-BLINDNESS.

Mr. President and Gentlemen,

Colour-blindness having for the last few years occupied so much of the attention of the literary and scientific world, I wished to ascertain to what extent that defect exists among the rising generation of this community. With this view we formed a commission, consisting of Dr. Cumming, Dr. Pickering, and myself, and, with the permission of the School Board, we visited several schools and examined upwards of 2000 children. I propose in this paper to submit the result of our examination to this Society.

It is a comparatively recent subject. The first cases of colour-blindness were published by Joseph Huddart in the *Philosophical Transactions*, London, 1777. But the subject excited little interest till the year 1794, when the celebrated English chemist Dalton, who was colour-blind, published an account of his own case, which attracted so much attention —it being considered a rare curiosity—that subsequent writers called the defect Daltonism.

In 1805 that stupendous genius Goethe published a treatise on the pathology of colour-sight. In 1837, Professor Seebeck was the first to examine a

number of colour-blind persons, and to classify the degrees of their abnormal condition. But the most important work on the subject was that of Dr. George Wilson, Professor of Chemistry in Edinburgh, which first appeared in the *Monthly Journal of Medical Science* for November, 1853. "My own special attention," says Wilson, "was directed to the subject from the blunders which I found many chemical pupils make in reference to the colours of compounds. After making every allowance for imperfect exposition on my part, and insufficient attention on the part of my students, and after also making a large deduction for inaccurate answers on the score of imperfect rememberance and inability to name colours, I still found, in the laboratory and lecture-room, that many a pupil was puzzled to describe the changes which occur when an acid or an alkali acts upon a vegetable colouring matter, although, to a normal eye, these changes are of the most marked character, and that, in general, I could count with little confidence upon accurate answers to questions regarding the colours of bodies."

A great deal has since been written on the subject, both in France and Germany. The most comprehensive and excellent treatise on colour-blindness appeared recently by Professor Holmgren, of Upsala, Sweden.* It is only just to the Edinburgh professor to say that some of Holmgren's striking points are due to Wilson's suggestions.

* De la cecité des couleurs dans ses rapport avec les chemins de fer et la marine. Paris, 1878.

Great credit is due to Dr. Joy Jeffries, of Boston, for his valuable efforts to direct public attention in America to that subject. Dr. Stilling, of Cassel, and Dr. Cohn, of Breslau, have also given us valuable contributions to the study of this subject, and my excellent friend, Dr. Hugo Magnus, of Breslau, has written several *brochures* which have called forth high eulogiums from Mr. Gladstone, who published a paper on "Colour Sense of Homer" in the October number of the *Nineteenth Century* in 1877. Mr Gladstone's paper was mainly instrumental in directing public attention to the subject in this country—the more so, that it was at a time of feverish political excitement that England's great statesman and scholar was able to shake off Russ and Bulgarian, and to devote some hours to the study of the "Colour Sense of the Homeric Period." I propose to speak to you this evening on perception of colour in its practical bearing upon certain occupations, especially *employés* on railways and sailors. A few introductory remarks on the physiology of vision will facilitate the treatment of the subject.

COLOUR-SIGHT.

The eye is the organ which brings us into contact with the world around us, by giving us an image of objects; of their size, shape, and colour. The medium through which this effect is produced is primarily the retina and optic nerve. The retina receives the impression of light and colour emanating from objects, which impression is conveyed to the brain by means of the fibres of the optic nerve. This is the organ of vision in its most rudimentary form, as met with in the lowest forms of animal life, consisting of a nervous cord, and colouring matter for absorbing the rays of light. But in ascending the scale of animal life, we have the visual organ in a degree of perfection and development commensurate with its requirements.

The human eye in its totality may be regarded as a photographic apparatus, consisting of retina to receive the image, compound lens for refraction, and camera. It has, in addition, an adjusting mechanism, an optic nerve to conduct the impression, nerves for regulating its movements, and nerves for its nutrition. When we consider that the eye is a self-adjusting apparatus, serving the purposes both of telescope and microscope, and that the retina is a kind of plate, which not only receives the impression of objects from without, but upon which also are registered the changes that are going on in the

brain, heart, kidneys, and other organs, and that its materials are composed of organic substances subject to structural changes, we must admit that, with all its optical imperfections, the eye is an instrument not lightly to be spoken of.

That the retina is a membrane corresponding to the photographer's plate, is a statement which I could not have made to you two years ago. All that we then knew of the retina was, that it consisted of five layers, and that the outer layer (rods and cones) was the impressible membrane which Heinrich Muller demonstrated in 1847, but by what mechanism we were left to mere conjecture. It is only two years since Professor Boll, of Rome, published his observations on the photo-chemical action of the retina.

Experiment.—Take a frog, and keep it in darkness for some time, then decapitate it, and keep the head in a dark place for twenty-four hours; remove the eyeball, open it, and examine the retina, which you will find of a beautiful red colour; expose it to the sunlight, and the red gradually disappears, the membrane gets pale, then yellowish, then it becomes like white satin; ultimately, this appearance is gradually vanishing, and the retina becomes quite transparent. This red principle of the retina, which is generated in darkness, and decomposed in sunlight, Boll calls *erythropsine*. That it exists after the death of the animal, shows that it is not a transitory property, but a durable chemical element of the retina, analogous to the hæmogoblin of the stroma of the red corpuscles of the blood.

The *erythropsine* is transformed by the light into several physiological combinations, the same as hæmogoblin is changed by the action of different gases. The different chemical combinations resulting from the action of light upon the erythropsine—in other words, this photo-chemical process—constitute the essence of the perception of light and colour.

There is another factor in this physiological laboratory which we must notice—namely, behind the retina there is a layer of epithelium, covered with pigment cells of hexagonal shape. These cells contain oil globules, which Boll considers to be the primary materials from which the erythropsine is incessantly reproduced.

These peculiarly shaped pigment cells behave very curiously. They seem to be migratory cells. When the eyes have been kept in a dark place or in a red or yellow light, the retina can be easily separated from the pigment layer, as a distinct membrane; but when the eyes are exposed to white, green, blue, or violet light, the pigment extends into the interstices of the retina, and the rod and cone layer cannot be separated from it.

The experiments made by Boll upon frogs, and cartilaginous and osseous fishes, have been repeated with the same result upon the human subject by Professors Schenke and Zuckerkandel of Vienna, after a capital execution.

A propos of the photo-chemical theory, it appears to me to bring us one step nearer to a comprehension of the intimacy which exists between mental

operation and physical action. Without losing myself in metaphysics, I would merely indicate that it shows us that the image of objects is actually impressed on the retina, which the mind stores up: memory is the faculty of bringing forth these plates when required. Thus, the analogy between the retina and the photographer's plate is strictly correct, only that the retina gives us a chromo-photograph.

Now with regard to the perception of colour. Newton has demonstrated that white light, as emitted from the sun or from any luminous body, is composed of seven different kinds of light. If we admit a beam of the sunlight through a small hole in the window-shutter of a dark room, it will go on in a straight line and form a round white spot on the wall. If we now interpose a prism whose refracting angle is such that this beam of light may fall upon its first surface and emerge at the same angle from its second surface, and if we receive the refracted beam upon a screen, instead of a white spot there will be formed upon the screen an oblong

Fig. 1.

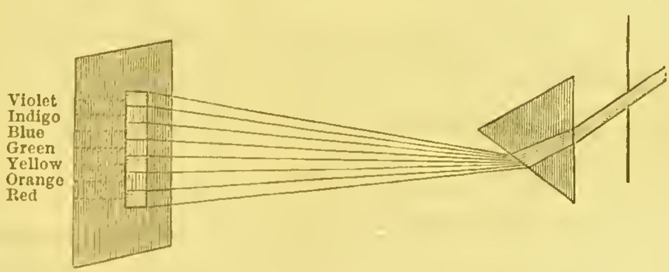


image of the sun, containing the seven colours. This image is called the solar or prismatic spectrum. These seven colours are called primary colours, because they cannot be decomposed: pass one of

them through a prism, and it will merely be bent, the colour still remaining the same. All colours used in the industries are only mixtures of different pigments, which are decomposed by the prism.

The requirements just indicated for producing the image not being always at our disposal, an instru-

Fig. 2.

ment called Spectroscope has been devised for that purpose, which is of the following construction:—

1. A Telescope, with a positive eye-piece on one end, and a slit regulated by a screw on the other, which is directed against the sun or gaslight.

2. Compound prism, consisting in all of five prisms, to give a considerable dispersive power separating the different colours of the spectrum as widely as possible.

3. Collimator, which is a contrivance to render rays from a slit parallel by means of a lens placed at its own focal distance from the slit. The rays are thereby filtered, as it were, to prevent the mixture of rays of different colours.

Mr. Browning, who makes Spectroscopes of great precision, has constructed for me an instrument (Fig. 2) specially adapted for detecting Colour-blindness. It consists in having a second slit which moves in the focus of the positive eye-piece. A slight movement enables this to give an isolated ray of any particular spectral colour.

Adopting the undulation theory of light, and looking at the solar spectrum, we find that red, which has the longest wave, is the least refrangible colour; whilst violet, which has the shortest wave, is the most refrangible; and green, which has the medium length of wave, occupies the middle of the spectrum or is of medium refrangibility.

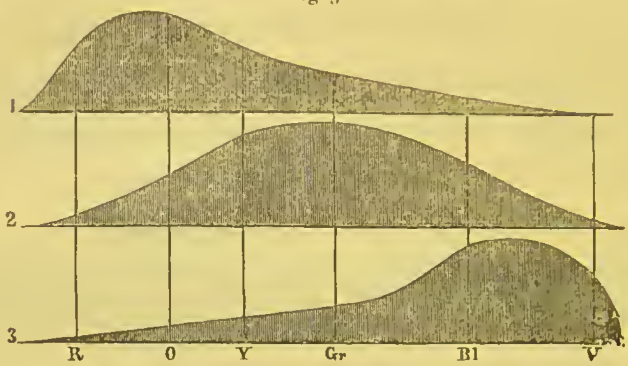
Upon this simple view of the subject is founded the theory of perception of colour, first propounded by Thomas Young, and lately defended by Helmholtz,* which is generally adopted under the name of the Young-Helmholtz theory, which is this, that the retina has three distinct kinds of nervous elements, or fibres, each of which perceives one of the three fundamental colours, red, green, and violet. The first of these elements is excited in the highest degree, by the red rays, but also slightly by the green, and feebly by the violet rays. The second category is impressed by the green rays, and also feebly by the red and violet rays. Thirdly, the violet rays excite strongly the elements of the third category, which are little sensible to the green rays, and in a still less degree to the red. Every one of these elements, when excited, transmits to the brain the impression of its own fundamental colour. The impression of the intermediary colours is given by the excitation of two or three of these groups in different degrees. When all the three are equally excited, the result is white or grey colour.

This theory, although the only explanation we

* Optique Physiologique Paris, 1867.

are at present able to give of chromatic perception, yet, as microscopic anatomy has never demonstrated

Fig. 3



NOTE.—This figure of Helmholtz explains his theory :—1 expresses the different degrees of excitation of red; 2, that of green; 3, that of violet. The vertical lines indicate the relation of the different coloured rays to the three nervous elements. The red, green, and violet rays (ought to) touch the highest points of the figures. The other lines also indicate the degree to which they excite the different retinal elements, by the extent to which they encounter the different figures.

these three fibres, we must still regard as merely a hypothesis and provisional, which may belong to the same class as that of luminous perception, prior to Boll's discovery of the photo-chemical process. But, with this new point of departure, I venture to think that we may yet construct an ophthalmo-spectroscope, or another apparatus to explore the retina, and chemists may yet succeed in analysing the *erythropsine;* we may perhaps find in it a more simple explanation of the perception of colour. The little that we do know of the behaviour of *erythropsine*, under the influence of various coloured rays, is sufficient to show, that it is an important factor in chromatic as well as in luminous perception.*

* 1. In complete darkness, retinal red is like the middle of spectral red.
2. After long exposure to solar rays, the retina becomes colourless.

Since writing the above, I received a communication from Professor Boll, informing me that he had several interesting conversations with Helmholtz on this subject. He says: "On the main point of the question, Helmholtz agreed with me entirely, but some of his observations contributed very largely to correct my first views. I still continue to retain as certain the Young-Helmholtz theory that every sensation of colour is composed of three different sensations. I admit in the retina the existence, not of three nerve-fibres, but of three different kinds of percipient organs—viz. 1st, the pigment cells; 2nd, the cones; 3rd, the rods. Every sensation of colour is threefold, being composed of three different irritations—the irritation of the pigment cells, the irritation of the cone, and the irritation of the rod. Helmholtz agrees with me, that the proofs for this new theory are quite sufficient." He read a memoir before the Academia dei Lincei, entitled "*Tesi ed Ipotesi nelle Sensazione della Luce e dei Colori*," which

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3. In red light, retinal fundamental red becomes more saturated like Pompeian or brownish red.
4. Yellow light does not much alter the fundamental colour of the retina, but renders it a little brighter.
5. Green light:—
   (*a*) The action of an intense green light, when of short duration (or one of medium intensity prolonged), changes the fundamental colour into purple red, which, getting paler, turns into rose colour.
   (*b*) When an intense green light is prolonged, the red purple passes off, becomes paler, and at last colourless.
6. Blue and violet:—
   (*a*) When of feeble intensity (or intense and of short duration), the colour changes into a muddy violet.
   (*b*) When the intense rays are prolonged, the violet is effaced, and the retina becomes quite colourless.
7. Ultra-violet rays have no physiological action upon the retina, however long they are continued.

will be published next month. Meanwhile, it is satisfactory that I am able to communicate to this Society what may be the scientific basis of colour-perception of the future.

Every healthy retina, then, receives an impression of different lights and also of different colours. In a state of disease, there are abnormal sensations of colour, as, for instance, in some forms of atrophy of the optic nerve, in hysterical epilepsy,* and in the case of habitual drunkards, etc.; but every retina, in the exercise of its healthy functions, is capable of receiving the impression of colour and its various shades, and of communicating that impression to the brain. The acuity of perception of the different shades may be developed by practice, the same as the ear to notes, but that physiological faculty cannot be absent, unless in exceptional cases, when we must regard it in the same light as hare-lip, cleft palate, deficiency of fingers or toes, or any other congenital abnormality.

The theory advanced by Magnus is, that man, in his primitive condition, had no perception of colour; in the next stage of developement, red and yellow became visible; in the third, green and its varieties; and in the fourth, blue and violet came to be recognised. He thinks that will account for the

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* Considering the justifiable scepticism among the profession about the vagaries of hysteria, because they cannot be reconciled to physiological principles, I would merely mention here the demonstrations given by Prof. Charcot at the Hospital de la Salpêtrière in Paris. These demonstrations go to prove that hysteria in all its phases follows a course of mathematical regularity. The ease with which he makes hemi-anæsthesia and colour-blindness to oscillate from one side to the other is certainly very remarkable.

confused manner in which the ancient writers describe colours. Indeed, in speaking with a well-educated colour-blind person, he was reminded of reading Homer.

Mr. Gladstone, who twenty years ago was struck with the fact that Homer's colour-adjectives and colour-descriptions of the poems were not only imperfect, but highly ambiguous and confused, says, "I rejected the supposition that this was due to any defect in his individual organisation, and found that his system of colour, or rather his system in lieu of colour, was founded upon light, and upon darkness its opposite or negative, and that the organ of colour was but partially developed among the Greeks of his age." Now, Magnus, adopting the development theory, has with great erudition endeavoured to reconcile it with the physiological action of the retina, and Mr. Gladstone finds in it countenance for the opinions he had long since expressed with regard to the Homeric Poems.

From the views given above of the physiological action of light on the retina, it will be seen how entirely I differ from Dr. Magnus, as also from Mr. Gladstone's reading of Homer.

Does the Homeric text shut us up to the conclusion that either the poet or the whole Greek nation were colour-blind?

It appears to me very difficult to entertain such a view. The Greeks of the Homeric period could not have been colour-blind, when we find that all the colours of the spectrum are found in their language. They have μέλας, black; λευκός, white;

ἐρυθρός, red; φοῖνιξ, dark-red; ξανθός, auburn; χρύσεος, golden; χλωρός, greenish-yellow; κυάνεος, blue; πορφύρεος, purple. That Homer sometimes misapplied the terms has nothing to do with the question; it is quite a common occurrence in the poetry of our own advanced age. The expressions κροκόπεπλος 'Ηώς, saffron-robed Aurora, and ῥοδο-δάκτυλος 'Ηώς, rosy-fingered Aurora, are exquisite personifications, although the tints of the rising sun may not correspond to a nicety to rose or saffron colour. The *realistic* word-painter Dante has also pictured Aurora—

> " Si che le bianche e le vermiglie guance,
> Là dove io era, della bella Aurora,
> Per troppa etate divenivan rance."—(*Purgat.*)

Of which the following is a faint rendering:—" So that, there where I was, the white and vermilion cheeks of beautiful Aurora have, through advanced age, become of orange hue." Bearing in mind what Macaulay* says of the Florentine poet, that "his Divine Comedy is like Gulliver, a personal narrative, that he is an eye-witness and an ear-witness of that which he relates. His own hands have grasped the shaggy sides of Lucifer. His own feet have climbed the mountain of expiation. His own brow has been marked by the purifying angel. He represents the gigantic spectre of Nimrod: his face seemed as long and as broad as the ball of St. Peter's at Rome, and his other limbs were in proportion; so that the bank which concealed him from

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* Essay on Milton.

the waist downwards nevertheless showed so much of him that three tall Germans would in vain have attempted to reach to his hair." Looking upon it in this point of view, we must admire this perfect picture as characteristic of, and in keeping with, his *intense realism*; but it cannot be admitted as superior if at all approachable, to the sublime suggestive touch where

Ἠὼς μὲν κροκόπεπλος ἐκίδνατο πᾶσαν ἐπ' αἶαν

—saffron-robed Aurora was spread over all the earth. Still less can we make of Homer's varied application of the term πορφύρεος, purple, for this colour is not found in the spectrum, but is a mixture of its two extremes—viz., red and ultra-violet. It may, therefore, with propriety, be applied to female robes, to the rainbow, to blood, cloud, etc.

We may notice, in passing, the manner in which Homer treats ladies' eyes. Juno, as the queen of gods, the dignified matron of Olympus, is described as Βοῶπις Ἥρη (ox-eyed)— meaning a large, round, dark eye; while Minerva, the goddess of wisdom, is described as γλαυκῶπις Ἀθήνη, which we were taught to translate "blue-eyed Minerva," until informed by the high authority of Mr. Gladstone that it does not refer to colour at all, but it is to be translated "bright or flashing eyed." There is no doubt, however, that the Greeks used γλαυκῶπις to signify blue-eyed, for Herodotus speaks of the Budini, a Scythian tribe, as γλαυκὸν και πυῤῥόν, blue-eyed and red-haired.

Among the interesting communications which Mr.

Gladstone's article has called forth, is one by Herschel, in *Nature* for November 28, 1878, who calls attention to the fact that Homer, once at least, styles himself "a downright blind man"; and Herodotus, in his life of Homer, states that "he was born 167 years after the Trojan War, and when still a child was adopted by his stepfather, to whom he succeeded in the management of a school. At an early age, however, he set out for distant voyages. When about thirty-four years of age, he lost his sight from a chronic disease of the eyes. Previously, when at Ithaca, he had a narrow escape from that calamity." Judging from this epitome, I think it most probable that he was neither blind nor colour-blind, but his vision was dim from an attack of Egyptian ophthalmia, which he contracted on his voyage. The quotation from Herodotus just referred to can hardly be construed into anything else than a relapse of that affection which he contracted at Ithaca. In the East a blear-eyed person is called blind, hence Homer may have been suffering merely from partial opacity of the cornea, the consequence of the affection just mentioned, which a strolling minstrel is most likely to get.

I examined a large number of discharged soldiers and others suffering from Egyptian ophthalmia (some in its most aggravated forms), and I found that the perception of colour was not prejudiced thereby.

Reference is made by Mr. Gladstone to the Prophet Ezekiel (i. 27, 28), who was also in a backward state in regard to colour-perception.

The prophet describes the rainbow—"I saw, as it were, the appearance of fire, and it had brightness round about. As the appearance of the bow that is in the cloud in the day of rain, so was the appearance of the brightness round about," which, Mr. Gladstone thinks, cannot be explained but by supposing that, for the eye of the prophet, red was the fundamental and exclusively prevailing colour of the rainbow. We are not told whether we are to infer that the Prophet Ezekiel himself was colour-blind, or whether the Jewish nation of that period were in a backward state. If the Homeric argument is to apply to Ezekiel, it would be very remarkable indeed, for in that case the Jewish nation, instead of progressing in the appreciation of colour, must have sadly degenerated, for we find that nine centuries before Ezekiel, when they had just escaped from Egyptian bondage (Exodus xxviii. 17-21), Moses commanded the children of Israel to set the breast-plate of the High Priest with twelve stones. Amongst these were the carbuncle, emerald, sapphire, amethyst, etc., representing all the spectral colours. That the primitive man was not born with an absolute blindness to colour, and that his chromatic perception was not left to progressive education of the eye, is proved from the fact that the mother of mankind could distinguish the colour of the fruit, for she saw it "beautiful to the eye," and we know that a colour-blind person cannot distinguish ripe cherries, strawberries, or apples, from the leaves, except by the form.

It appears, therefore, that Magnus, misled by the

beautiful Darwinian theory of development, has entangled Mr. Gladstone in a hypothesis, which, from a physiological as well as from a historico-critical point of view, cannot be seriously entertained.*

But the ethnological question, however interesting, sinks into insignificance when compared with the practical aspect of the subject, which involves the interest and safety of the public.

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* In thus speaking of Magnus's views, I refer only to "Die geschichtliche Entwickelung des Farbensinnes" (Leipzig, 1877); but we are indebted to him for his excellent publications on the subject, "Die Farbenblindheit" (Breslau, 1878), and "Beiträge zur kentniss der Physiologischen Farbenblindheit," in *Graefe's Archiv* (Berlin, 1878). It is also with great pleasure that I embrace this opportunity of expressing my high appreciation of his Ophthalmoscopic Atlas, which I think cannot be surpassed.

COLOUR-BLINDNESS.

Colour-blindness may be either—

1st. Total inability to discern colours (Achromatopsy);

2nd. False vision of colours (Chromato-pseudopsis); or

3rd. Difficult or blunted perception of colours (Dyschromatopsy).

The first kind is very rare. Professor Wilson records a case of a house-painter, in whom the perception of black and white was all that existed to represent the colour-sense.

In all other subjects of chromato-pseudopsis there is either an inability to discern a single colour, such as red, green, or violet, or there is an inability to discern the difference between two colours, such as red and green. Blindness to violet and its varieties is less frequent. In my examinations I have only met with one case where neither blue nor violet could be seen in the spectrum. Cases of bluntness of perception, on the other hand, are of comparatively frequent occurrence. It is only right, therefore, that the public should be impressed with the fact, that, taking the *ensemble* of all the varieties, colour-blindness is of more common occurrence than is generally supposed. Indeed, when I commenced to investigate the sub-

ject, I was astonished to find the number of cases which obtruded themselves, as it were, upon my notice.

Case I.

When I asked a friend of mine (a solicitor) to introduce me to the railway company to obtain information with regard to railway signals, he informed me that he himself was colour-blind. I had met him frequently in town, and in the country on fishing excursions and when collecting heather, without ever suspecting such a defect. On examination, I find his sight normal, but his eyes get sore when he looks at a bright-coloured object, such as a carpet. Looking into the spectroscope, he sees only blue; the rest looks to him like a glare of fire when seen through transparent gauze. When shown a scale of colours, his vision of

Black.... Blue ..... White... Yellow..	is	Correct;
Light Green		White;
Green		Uncertain;
Dark Green		Black.

Here, therefore, is a case of inability to discern both green and red—he is green and red-blind. He has a brother who was engaged in a wholesale warehouse and was put into the silk department, where he committed such blunders in regard to colours that he had to leave the trade, and he is now head engineer of an Atlantic line of steamers.

Case II.

When I asked Dr. Cumming and Dr. Pickering to undertake the examination of the schools, each of these gentlemen mentioned a case of colour-blindness among their friends. Dr. Pickering introduced a gentlemen, Mr. A., a manufacturing chemist of twenty years' standing. His vision is perfect, and he is never fatigued in reading. He knows that grass is green, having been told so from infancy, otherwise he would take it to be yellow, about which colour he never makes any mistake. He takes red berries to be green, but a shade lighter than the green leaf. In the spectroscope he sees blue and orange; he knows that there is something else, but cannot venture upon any name. He has a good ear for music—so acute, indeed, that he can detect the slightest sharpness or flatness of a note. He was the conductor of a choir. With the colour-scale—

Crimson................ is	.................Grey;
Scarlet..... Orange.... Salmon....	....................................Uncertain;
Lemon and Yellow	....................Correct;
Light and Dark Green	No colour—different degrees of brightness;
Light Blue and Indigo	..............Correct;
Violet	....Blue;
Purple	....Indigo.

Gaslight improves the red, but makes no difference to the other colours.

For chemical tests he has to rely entirely upon other parties. His grandfather and maternal uncle were colour-blind.

Case III.

Dr. Cumming introduced Mr. B., a merchant in town, who is remarkably clever in the appreciation of designs; in the blending of colours he generally succeeds fairly, but sometimes he makes ridiculous mistakes. In his case—

Pale Green	is	Shetland Grey;
Bright Green		Drab, or Fawn;
Dark Green		Purple;
Crimson, Scarlet, Orange		Doubtful Red;
Light and Dark Green		Drab;
Salmon, Lemon, Yellow		Yellow;
Blue		Correct;
Violet		Blue;
Purple		Indigo.

The difference between certain shades of fawn, green, and red, is to him no contrast at all, but he seems to know them, in his warehouse, in a kind of catalogue way. Therefore, he is totally green-blind and deficient in red: for instance, a piece of scarlet cloth thrown upon a bright green ground is not readily picked up. He is hypermetropic (H 14 left, and 10 right); hearing of left ear is rather deficient. There is also an eye-history in his family.

Case IV.

The Treasurer of the Philosophical Society introduced to me a gentleman, Mr. D., who is a shawl manufacturer. Tested with colours—

Pale Green.............. is ....Dirty White;
Green .....
Yellow.... } Yellow of varying brightness;
Orange...
Scarlet..................................Correct;
Dark Green ....Red;
Blue.......................................Correct;
Violet.....................................Blue;
Purple....................................Indigo.

Therefore, he is totally green-blind. In the spectrum he sees all the colours except green, which is similar to red, but of a lighter shade, as if some yellow had been mixed with it. Crimson he calls green; scarlet, red; orange, light red; salmon colour he considers to be light green; the vision of orange, yellow, and blue is correct; ultra-violet has the same appearance as indigo. He is an only son. His mother, who is seventy, has excellent sight, is not near-sighted, and has never required spectacles for reading; *her brother* was colour-blind.

I have entered into details of these four cases, because they are typical, representing the forms of the defect which are usually met with, and because the subjects, being gentlemen of intelligence, were, in addition to the objective tests, able to give accurate account of their subjective sensations.

Cause.—I have already mentioned that some cases

are caused by disease; but generally it is congenital, an inheritance transmitted from maternal relations. It is most probably caused by the intermarriage of cousins or other near relations. Hence, very likely, why Quakers furnish a large contingent of colour-blind. Dr. Wilson records six males in one family—uncles, nephews, and cousins—who were all markedly colour-blind, which defect had descended to them from their maternal uncle. They all belonged to the Society of Friends. One of them, a minister of that body, bought for his wife a bottle-green dress, and for himself a coat of bright scarlet, instead of the conventional drab of the Society.

When colour-blindness is caused by disease it may be cured, but when it is congenital it is incurable.

Seeing that the peculiarity of most colour-blind people is to mistake red for green, or to ignore a certain shade of red altogether, and to take green for yellow, the subject assumes a practical importance in connexion with railway signals, and lights in sailing-vessels, steamers, and lighthouses. The significance of railway signals is as follows:—At night a red light signifies "danger"; a green light, "caution" or "not sure"; and a white, "proceed." In the daytime red semaphores are used. When at a right angle to the post, the signal means "danger"; at forty-five degrees, "proceed cautiously"; and when folded in, "road clear." By the regulations of the Board of Trade, every sailing-vessel must, from sunset to sunrise, carry a green light on the right or starboard side, and a red light on the left or port side; and steamers must have, in addition, a

white light at the mast-head. This last is visible for five miles, and the side lights for two and a half miles' distance. The rule for meeting vessels is to keep red to red, and green to green. The colours indicate to the officer on duty the direction in which the ship is proceeding, and the relative position of both vessels. In lighthouses there are, generally, revolving and intermitting white lights, sometimes red ones, rarely green.

The practical bearing of this question, therefore, is that red and green being of necessity the very colours used in railways, sailing-vessels, and steamers, as well as in lighthouses, a colour-blind person may be the engineer of a train running a mile a minute, and the passengers' lives depend upon his clear perception of the difference between a red and green light. He may mistake the danger signal red for grey or white, or when it appears black he may not see it at all; and he may take the green for the yellow or safety signal. Or he may be the pilot on a steamer, and cannot say whether the light directly ahead of him is red or green, and hence cannot steer so as to avoid a collision.

It is this aspect of the question to which Wilson directed his attention:—"Struck by the danger which attends the use of coloured signals on railways if any of the signalmen are colour-blind, and satisfied from published statistics of colour-blindness that it must present itself in the army of railway servants spread over Europe and America, I brought this aspect of the subject before the Scottish Society of Arts, and I am happy to say that the publication of

my paper has induced the Great Northern Railway Company to require that in future all their officials shall be tested as to their freedom from colour-blindness before they are admitted."

It may well be asked, How is it possible for a colour-blind engine-driver, for instance, to perform his duty for any length of time without exposing his deficiency? But the explanation given by Holmgren is simple when we remember that a colour-blind person may come to distinguish between red, green, and white lanterns or flags, and even learn to call them by their right names, whilst all the time it is not colour which he sees, but he differentiates by the degree of intensity of light. The green is to him, as also to the normal eye, the deepest and darkest, the red is the most brilliant. As to the lanterns, the red-blind always recognises the red light by its being darker than the green, and the yellow by its being clearer and more brilliant. The green-blind distinguishes also the red, which he finds more brilliant than the green. In short, the colour-blind person supplements his defective vision of colour by all secondary aids. He trains himself to notice differences which escape most other eyes; these differences serve him in lieu of colour. That is the reason why daily collisions do not occur on railways and at sea on account of colour-blind officials. But if these circumstances lessen the danger, they do not remove the liability to disaster. When we keep the broad facts before us, that the colour-blind man cannot distinguish between red and green, all his interpretation of

signals rests upon the intensity of light; he knows light only by its quantity, and has no notion of quality. Now, if it is a matter of calculation and not of perception, it is evident that any objective or subjective cause may disturb and upset all his calculations. A tarnished signal, an ill-trimmed wick, the colouring matter of the glass, its thickness, or a little moisture, water, or snow adhering to the glass, will render the light less luminous; and a lantern illuminates differently in clear and foggy weather. Subjectively, the nervous apparatus of the eye may, like all other parts of the system, vary in its sensitiveness; the same light is brighter to a healthy eye in repose than to an eye fatigued and weakened. Every modification of the intensity of light being for the colour-blind a change in colour, little dependence can be placed upon his recognition of signals. No one would entrust his life to an engine-driver who could only distinguish signals by the difference in the intensity of the light—to whom a feeble light would indicate danger; a medium, caution; and a strong one, safety; and yet these are just the conditions under which every colour-blind engineer has to perform his duty. Should he rely upon his neighbour, there is the possibility of his neighbour being either colour-blind or blunt of colour-perception. Besides, a great many are unconscious of their defect. Professor Holmgren reports that a large number of men, far from being convinced of their defects even after repeated examinations, gave all sorts of excuses for mistakes; they all insisted that they had excellent sight, and

had never experienced the slightest difficulty in distinguishing signals, and had never made the slightest mistake. What is required, however, for the safety of the public is a conductor who can pick up colours instantaneously, without measuring degrees of luminosity, or relying upon adventitious aids. The fact is indisputable that railway accidents have occurred from inability to discern the colour of signals.

With regard to Sea Signals, Dr. Rumberg has classified the reports of some marine accidents from 1859 to 1866; they were 2408 in number. Of these, 1562 were due to want of skill or carelessness of the ship's *personnel* or to accidents impossible to prevent; 215 to errors of the pilot or captain; 537 to want of observation or proper interpretation of the rules of the way; 94 to undetermined causes.

Under the last three heads, in the large number of 846, there is little doubt that some are attributable to colour-blindness, especially when we recollect the effect of fog on the colour of lights.

Tests.

From the preceding remarks it will be evident that all examinations based on the naming of colours are no tests at all; for a person may be deficient in his colour vocabulary, and yet have an acute perception of colour; whilst another may have learnt to attach the proper names to certain colours which he does not see, but of which he judges by the brightness of luminosity. Hence

also the reading of Snellen's coloured test-types and Stilling's red types on green ground, etc., can prove nothing in regard to colour-perception.

The test now generally considered the *experimentum crucis* is that originally proposed by Wilson, and elaborated by Holmgren. It consists in matching coloured skein worsted. You show a certain colour, which the person under examination is required to match. It is usual to begin with green and its shades, then go on to yellow, blue, and red.

Magnus, who examined 5,500 persons by this method, regards it as an absolute test, and recommends its general adoption throughout Germany. Cohn and Jeffries share his views in regarding it as a positive proof that a person's colour-perception is normal when he can match coloured worsted put before him.

Dr. Stilling is the only writer who does not think this test quite reliable. I have come to the same conclusion after careful trial. I have found that in some undoubted cases of colour-blindness the colours are easily matched. *To render this test of any value at all, the colour should be matched when seen at a distance.* After having tested a large number in the usual way, I had to abandon it, and resorted to examination in the following manner:—First, the person looked through the spectroscope, and was then asked to pick out from a heap of coloured worsteds the exact colours he saw in it; next he was asked to match colours held up, one after another, at a distance of six feet from him. I have no hesitation in saying that this test

is perfectly reliable. Goethe said, "You cannot reason for any length of time with an intelligent colour-blind man on colours without running the risk of getting crazy"; but the examination conducted in the manner just indicated is sometimes highly amusing.

STATISTICS.

Total number examined,	2,134
Colour-blind,	28, or 1·31 per cent.
Blunt of perception,	143, or 6·70 ,,
Examined with spectroscope, and at a distance of six feet from the colour to be matched,	398
Colour-blind,	12, or 3 per cent.

The subjects examined were all boys, for females are generally considered to be rarely deficient in colour-perception. Whether it is really the case, or whether they are more apt to conceal the defect, is uncertain. We have, however, found in the case of one colour-blind boy that his sister is also colour-blind.

COMPARATIVE STATISTICS.

Professor Wilson, Edinburgh,	5·6 per cent.
Dr. Stilling, Cassels,	5·0 ,,
Professor Donders, Utrecht,	6·6 ,,
Dr. Magnus, Breslau,	3·27 ,,
Dr. Cohn, Breslau,	3·6 ,,
Professor Holmgren, Sweden,	3·25 ,,
Dr. Jeffries, Boston,	5·0 ,,
Dr. Freris, France,	8·18 ,,
Dr. Favre, Lyons,	9·33 ,,
Glasgow Commission,	3·0 ,,

From these statistics* we are entitled to assume that of all *employés* on railways and at sea 3 per

* The difference in the results obtained by the various writers is easily explained when we bear in mind that neither of them takes cognisance of dyschromatopsy. Some of them take bluntness of perception for colour-blindness, whilst others disregard it altogether.

cent. are colour-blind, and 6·5 per cent. can perceive colours with difficulty; thus 9·5 per cent. ply their occupations amidst conditions approaching to uncoloured signals.

It is remarkable that, whilst Wilson's labours have been productive of good results in nearly all continental countries—in France, Germany, Sweden, Norway, Italy, Austria, yea, even in Russia, where there is a Government ordinance to guard against the admission of colour-blind railway *employés* and sailors into the service—no good has accrued so far as this country is concerned. No legislative enactment makes provision against the occurrence of such accidents.

On inquiry at the Caledonian Railway office, I find that every applicant for a situation on that line gets a printed certificate to fill up as to his health, etc. One of the questions is, whether the applicant has good sight and is capable of distinguishing colours. This certificate may be signed by any medical practitioner. This I consider a mere shirking of the responsibility. The companies do not consider themselves the guardians of the public; if the smash comes, they are not the responsible parties—there is the certificate signed by Dr. So-and-so! This may be quite well in a way; but it is not the principle on which life assurance companies conduct their business. They have their own medical referee, who is responsible to the company for every life he recommends.

On the North British system, the duty of examining the applicants is performed by the locomotive

superintendent. It is conducted, as you may expect, by showing the applicant different coloured cloths and asking him to name them; he is then examined in gaslight, the idea apparently being that that is a more rigid test of the discernment of colours.

After what I have stated above, no criticism is required to show that this is worse than no examination at all, because it tends only to confirm colour-blind officials in the conceit that they are quite capable for their duty.

The best provision against disasters from the cause under consideration would be, of course, an Act of Parliament. This is not only the most efficacious means, but also the most easily attainable. In the meantime railway companies and shipowners should be made to see that, as guardians of the interests of the shareholders—taking it from its lowest point of view—the shirking of such responsibility does not tend to the promotion of that interest. I have no doubt that if due stress be laid upon the point relating to vision and colour-vision, medical practitioners generally will soon acquaint themselves with this subject. But meanwhile it would be the most direct way to have the whole staff of officials properly examined by one competent to conduct the examination; for it is evident that, to be of any value, it must be conducted by one who understands the whole subject.

In conclusion I would remark, that it would be desirable to have hung up in schools diagrams of the spectral colours, and scales of various shades, to accustom the eyes of the young to them; for

just as the ear may be trained to the perception of musical sounds, so a great deal may be done in the way of educating the eye in the appreciation of the finer shades of colour, although colour-blindness when congenital is incurable.

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